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INVESTIGATION OF THE EFFECT OF DOPED FUELS ON FUEL SYSTEM

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INVESTIGATION OF THE EFFECT OF DOPED FUELS ON FUEL SYSTEM.

GENERAL.

The use of antiknock compounds in aircraft operation has practically become an absolute necessity for two main reasons, the constantly increasing use of higher compression ratios and the necessity for use of a cheaper fuel. This, the addition of antiknock compounds makes possible.

Accompanying the experimental use of a high test aviation gasoline containing antiknock, occurred the obstruction of the respective gasoline systems by considerable amounts of extraneous matter. It was found that the corrosion of the gasoline tanks and the subsequent accumulation in tubes and strainers of the corroded matter caused the obstructions of the lines. The belief arose that antiknock accelerated this action. It was considered advisable to investigate the effect of fuels and doped fuels on various materials in order to determine if these compounds would produce any injurious results on the fuel system.

PURPOSE.

The purpose of this investigation was to determine the effect of airplane fuels, dopes, and doped fuels on the fuel system, with particular attention to the problem of corrosion prevention.

CONCLUSIONS.

It is found:

1. That the following metals are very slightly, if at all, affected by doped fuels:

- (a) Aluminum.
- (b) Zinc.

2. That the following materials are very badly affected by such fuels:

- (a) Copper.
- (b) Brass.
- (c) Terneplate.
- (d) Iron.

3. That tin plate is moderately affected by these fuels.

It is to be expected, therefore, that considerable difficulty will be experienced with terneplate gasoline tanks and copper lines, brass jets, liners, etc., and to a less extent tin-plated tanks. Caution should be exercised in the use of each of these.

Reasoning by analogy, it is seen that alloys containing magnesium, cobalt, nickel, tungsten, copper, iron, and lead are apt to be very seriously affected by these fuels, while alloys containing aluminum, copper, zinc, and silicon (and in rare cases silver and platinum, as well as osmium and iridium) are apt to be quite resistant to these fuels.

MATERIALS.

The materials used in this investigation are determined by the nature of the materials used in a typical fuel system (see fig. 1). These materials are largely aluminum, copper, brass, steel, terneplate, and tin plate. Zinc

plate was included for the purpose of finding out how it stood up in comparison with the above. All of these materials were obtained in sheet form from stock at McCook Field, with the exception of the zinc plate, which was prepared in the chemical laboratory of the Material Section.

Rubber hose of the following description was included in this investigation:

Goodyear gasoline line, $\frac{1}{8}$ inch inside diameter.

Cloth wrapped gasoline line, $\frac{3}{8}$ inch inside diameter.

Unarmored pump hose, $\frac{3}{4}$ inch diameter.

This material was likewise obtained from stock at McCook Field.

The action of the following fuels on the above materials was investigated:

- (a) High test gasoline.
- (b) Low test gasoline.
- (c) Antiknock compound.
- (d) 91 per cent high test gasoline containing 9 per cent antiknock.
- (e) 97 per cent high test gasoline containing 3 per cent antiknock.
- (f) 50 per cent high test gasoline, 50 per cent benzol.
- (g) 84 per cent low test gasoline, 16 per cent antiknock.

The high test gasoline, low test gasoline, and benzol were obtained from stock at McCook Field. The antiknock compound is Antiknock No. 1. It was obtained from the General Motors Corporation, Research Division, Moraine City. It is claimed that this antiknock compound is composed of 70 per cent aromatic amines and 30 per cent benzol. The amines are probably orthotoluidine, paratoluidine, xylydine, aniline, or mixture of these.

A complete chemical analysis (page 4) was made on all metal stock used, and distillation curves (see fig. 8) were run on fuels. These data are included for purpose of reference.

METHOD OF PROCEDURE.

In the case of the metals, the sheet stock was cut into small strips 4 inches long and 1 inch wide. These were placed in the above fuels and doped fuels in such a manner that only half of the specimen was covered with the liquid. The other half was thereby exposed to atmosphere saturated with the vapors of each fuel. Two series were run in parallel; one series was placed in flasks which were securely stoppered so as to exclude all possibility of ventilation and entrance of moisture and, therefore, represented the conditions present in a gasoline tank which was partially filled with liquid and the rest of the tank filled with practically moisture-free air, saturated with the fumes of the fuel in the tank. The other series was run under identical conditions, with the exception that all flasks were allowed to remain unstoppered and were placed in a large container, which was sealed to prevent entrance or exit of fumes. This container was saturated with moisture vapor, thereby reproducing the conditions that are present in a partially filled gasoline tank

when the atmosphere is very high in moisture content. It was believed that this latter condition would impose a much more rigorous test on the materials than the above practically moisture-free series. This was found to be the case.

The rubber gasoline lines were tested from specimens made by cutting the hose into sections 6 inches in length, stopping one end with a cork stopper and inserting in the other end a 6-inch glass tube. The gasoline hose and

affected. The exposure extended over a period of 145 days.

DISCUSSION OF RESULTS.

It is observed that the metal which stood up better than any other examined is aluminum. Second to this is zinc, and third in order is tin, while steel, terneplate, and particularly copper and the copper alloy, brass, are very badly affected by fuels containing antiknock compounds.

DIAGRAM OF TYPICAL FUEL SYSTEM.

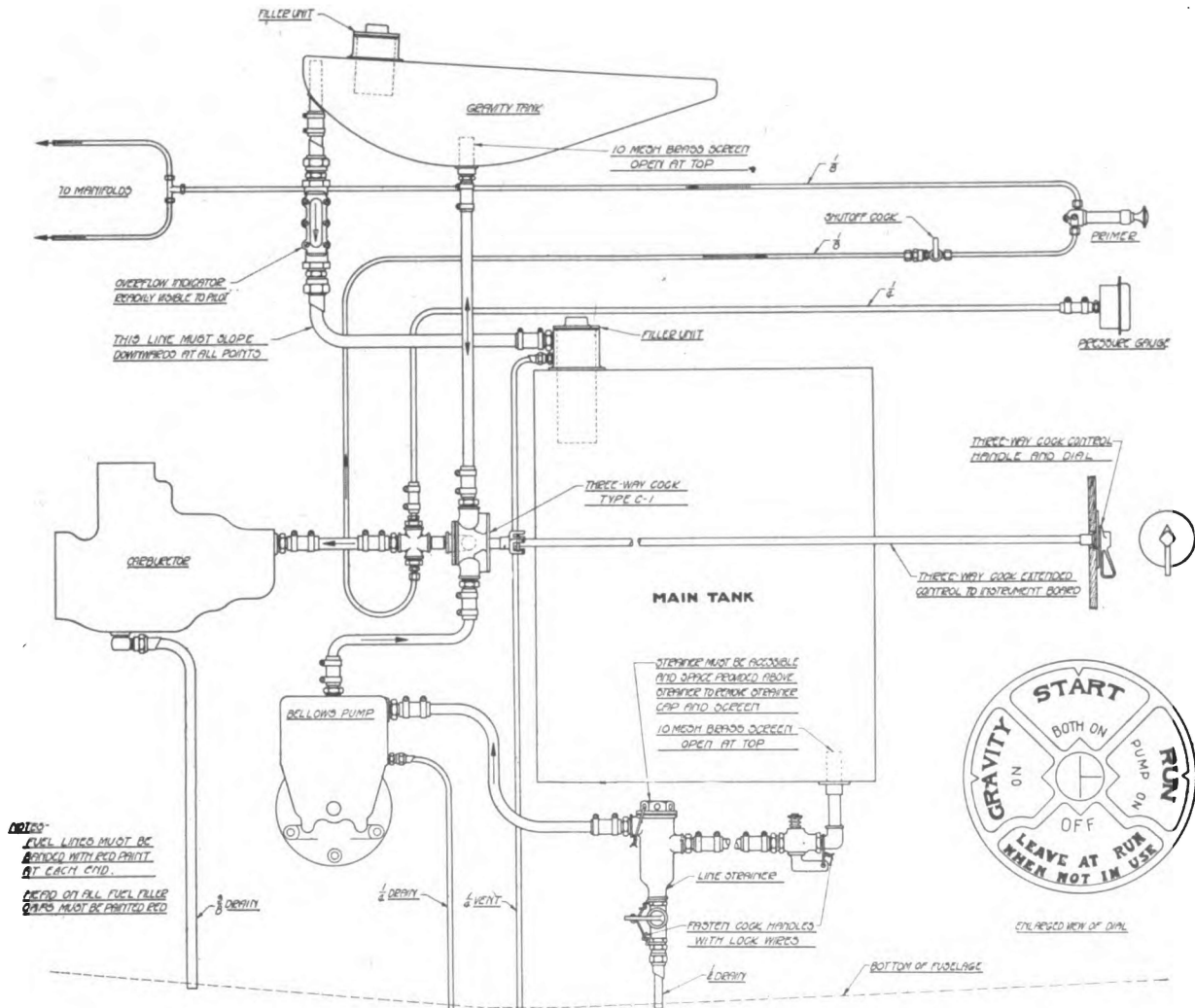


























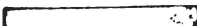







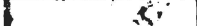



FIG. 1.—Materials used in fuel system.






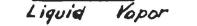












glass tube were then filled with the fuel and securely stoppered. The fuels in these tubes evaporated within a few days. The tubes were refilled and allowed to evaporate a second time. They were left undisturbed until the time of examination at the conclusion of the test.

RESULTS.

The results obtained in this investigation are charted in schematic form in figures 5 and 6. These data were obtained by noting the effect of the various fuels and doped fuels on the materials, and stating the results in the form of slightly or somewhat affected, badly affected, and un-

The deleterious action of these compounds on the metals present in the fuel system is considerably increased by the presence of moisture. Figure 2 shows the results of the action of fuels and doped fuels on the various metals in the absence of moisture. Figure 3 shows the action of these fuels in the presence of moisture. Figure 4 presents the metals in their original condition before the tests were begun. It will be noted that the metals in figures 1 and 2, which have been affected by the various compounds, are considerably darker than the originals shown. The actual corrosion which took place is very difficult to show by means of photograph. However, some idea of the relative

	<u>Sheet Aluminum</u> Liquid Vapor	<u>Zinc Plate</u> Liquid Vapor	<u>Sheet Copper</u> Liquid Vapor	<u>Sheet Brass</u> Liquid Vapor
High Test Gasoline				
Low Test Gasoline				
91% High Test Gasoline				
9% Anti-Knock				
97% High Test Gasoline				
3% Anti-Knock				
50% High Test Gasoline				
50% Benzol				
ANTI-KNOCK				

	<u>Sheet Steel</u> Liquid Vapor	<u>Tin Plate</u> Liquid Vapor	<u>Tin Plate</u> Liquid Vapor
High Test Gasoline			
9% High Test Gasoline			
9% Anti-Knock			
97% High Test Gasoline			
3% Anti-Knock			
ANTI-KNOCK			

Note:-
 The part of each specimen labelled "Liquid" was immersed in the fuel; the part labelled "Vapor" was exposed to the combined vapors of these fuels in air saturated with moisture.

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effects can be obtained by comparing the varying degrees of darkness of the samples as compared with their originals. It will be noted that the darkest samples, that is those that were most affected, are copper and brass. This "effect" was in the form of a combined corrosion of the metal and a deposition from the fuel, the total deposit being in the form of a tacky residue.

It is, therefore, to be expected that these compounds will affect, to a considerable extent, copper tubes, terneplate gasoline tanks, brass or bronze couplings, while aluminum housings, aluminum pumps, etc., will probably suffer only slightly, if at all.

Tin plate (dairy stock) can be expected to hold up much better than terneplate, and it is, therefore, a natural conclusion that dairy stock should be used for gasoline tanks in preference to terneplate.

The ideal material for gasoline tanks appears to be aluminum, for not only has aluminum withstood the tests of this investigation better than any of the other metals, but it has also been found that aluminum is the least

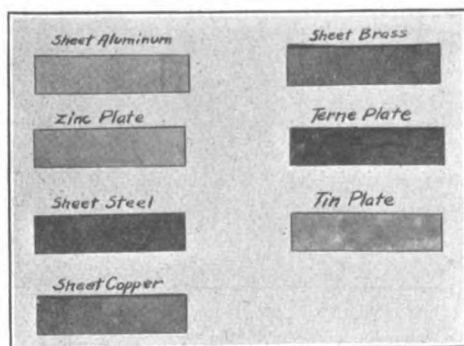


FIG. 4.—Original condition of material.

affected by sulphur and other compounds extracted by gasoline from rubber gasoline lines. (See Naval Aircraft Factory report on "Effect of corrosive material in rubber hose upon gasoline tanks") and that aluminum gasoline tanks suffer least from corrosion (see report "Tests on fuel tanks for aircraft," Naval Aircraft Factory). The corrosive action of doped fuels will be particularly marked if these fuels are allowed to remain for some length of time in the fuel system.

Reasoning by analogy, the results obtained from certain other metals and alloys of various metals can be anticipated after the manner outlined in figure 5. Figure 5 gives a graphical representation of the effect of antiknock compound on various metals, arranged in descending order of magnitude, that is, the metals at the top of the curve are probably the least affected, while those at the bottom of the curve are most affected, and those in between these two components are affected in the order of magnitude relative to their position.

It is, therefore, to be expected that alloys containing rather high percentages of aluminum, zinc, and in some rare cases, silver and platinum, will not be affected by antiknock compound, while alloys containing magnesium, copper, cobalt, nickel, and tungsten will be very greatly affected by such compounds, and alloys containing chromium, manganese, tin, and lead moderately affected. That is to say, it is to be expected that such

materials, as for example the B. G. spark plug, containing largely nickel with a trace of manganese, and the B. G. Ferronick spark plug, containing chromium, nickel, and iron, will both suffer considerable fouling from these fuels. It is possible, however, that the high heat of the cylinder may prevent this. Other materials containing such elements are certain to cause trouble if placed in the gasoline system.

In the case of rubber lines, it is believed that difficulty may be expected only in those cases where high percentages of antiknock compounds are used. It is to be expected that in such cases a thick gummy substance will accumulate in the lines and possibly in the tanks. This of course is prohibitive. The rubber lines subjected to the action of fuels containing small percentages of antiknock compounds seem to have suffered insufficient deterioration to warrant their consideration.

EFFECT OF FUELS AND DOPED FUELS ON RUBBER.

Goodyear Gasoline Line, 1/8-inch inside diameter.—No apparent effect of the above fuels on this line except that a heavy tacky deposit is formed when high percentages of antiknock are used.

Cloth wrapped gasoline line, 3/8-inch inside diameter.—Slight discoloration by all fuels and also some deposit. Antiknock produced a heavy tacky deposit.

Narrowed pump hose, 3/4-inch diameter.—No apparent effect produced by high-test gasoline, low-test gasoline, and benzol. Each fuel, using antiknock, discolored the inside of the hose and left more or less of a tacky deposit.

Straight antiknock produced the same deposit to a greater extent.

CHEMICAL ANALYSIS OF SHEET STOCK.

Tinned sheet steel, Specification No. 10207A: 5 pounds per base box of 112 sheets, 14 by 20 inches.

Terne sheet steel, Specification No. 10209A: 8 pounds per base box of 112 sheets, 28 by 20 inches:

Tin.....	per cent..	20.0
Lead.....	80.0

Sheet copper, 99.9 per cent copper.

Sheet aluminum:		
Silicon.....	per cent..	0.08
Copper.....	do....	4.00
Iron.....	do....	0.62
Aluminum.....	do....	95.30

Sheet brass:

Lead.....	Trace.
Copper.....	per cent.. 79.77
Iron.....	do.... 0.21
Zinc.....	do.... 20.02

Sheet steel, 0.023 ga., Specification No. 10201:

No. 1020 steel:

Carbon.....	per cent..	0.15-0.25
Do.....	do....	0.20-0.30
Manganese.....	do....	0.30-0.60
Do.....	do....	0.50-0.80
Phosphorus.....	do....	0.045
Maximum.....	do....	0.045
Sulfur.....	do....	0.050
Maximum.....	do....	0.050

Galvanized sheet steel, 0.001 inch thick:

Zinc.....	per cent..	99.9
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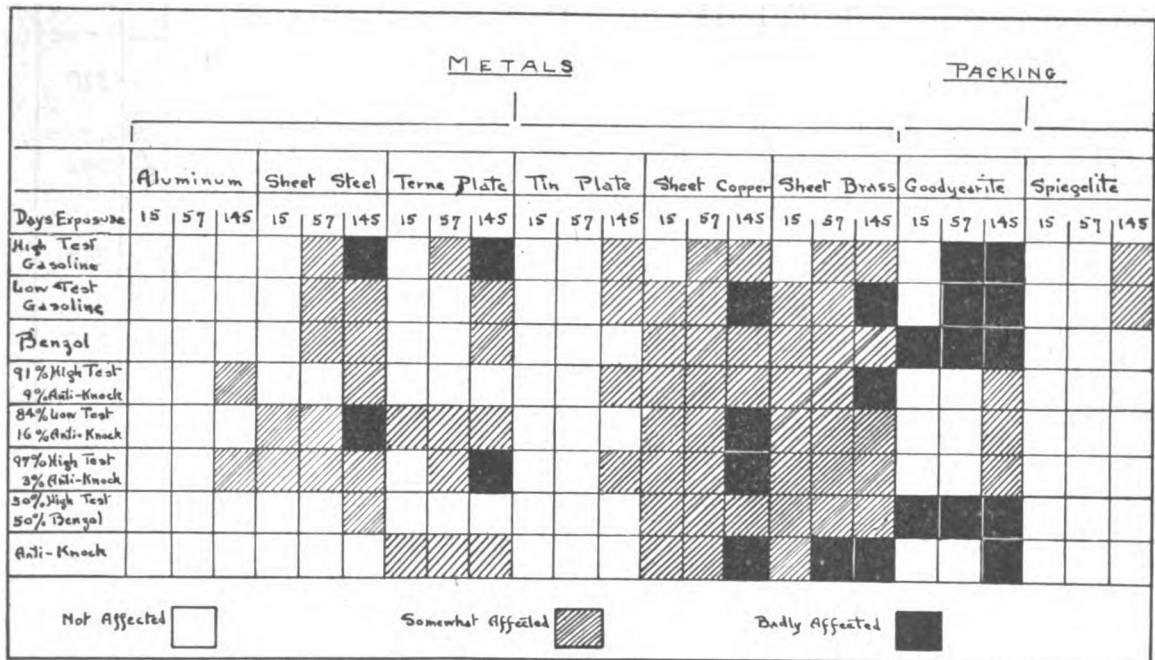


FIG. 5.—The effect of fuels on fuel systems in the absence of moisture.

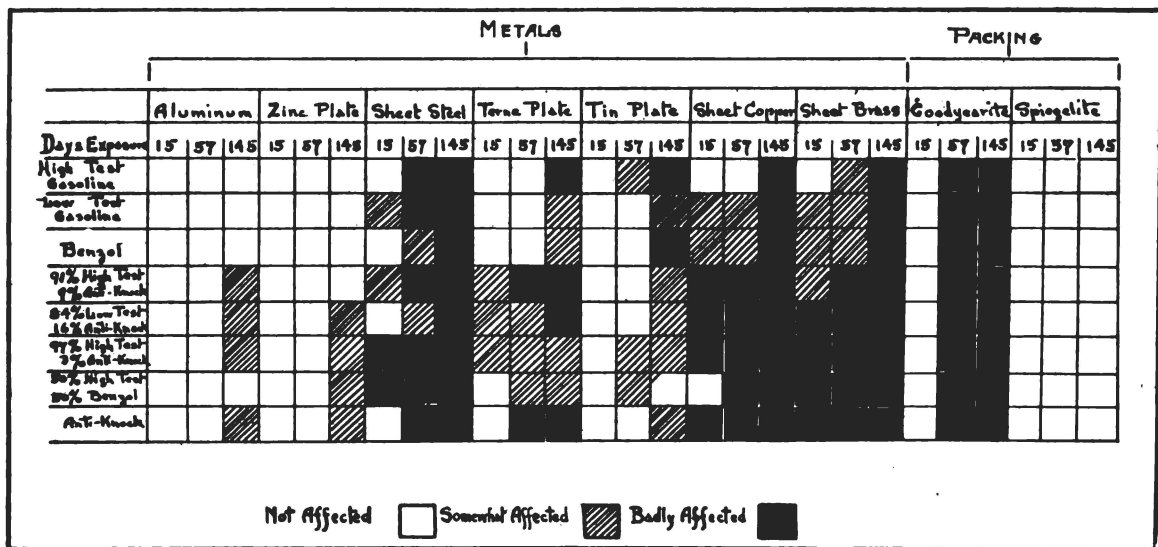


FIG. 6.—The effect of fuels on fuel systems in the presence of moisture.

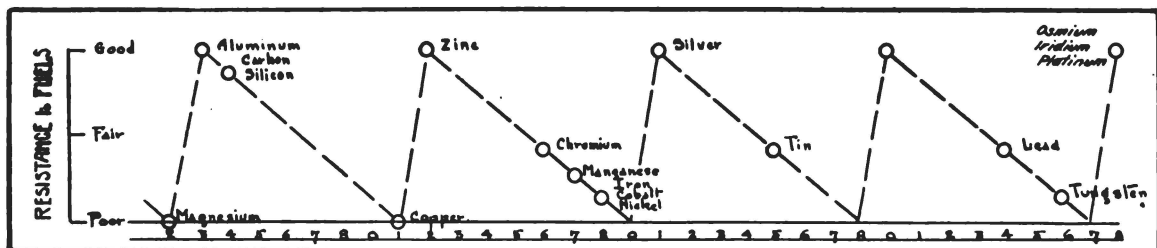


FIG. 7.

NOTE—From the above chart it is possible to predict the effect of doped fuels on various metals. The points aluminum, copper, zinc, tin, iron, and lead have been experimentally determined.

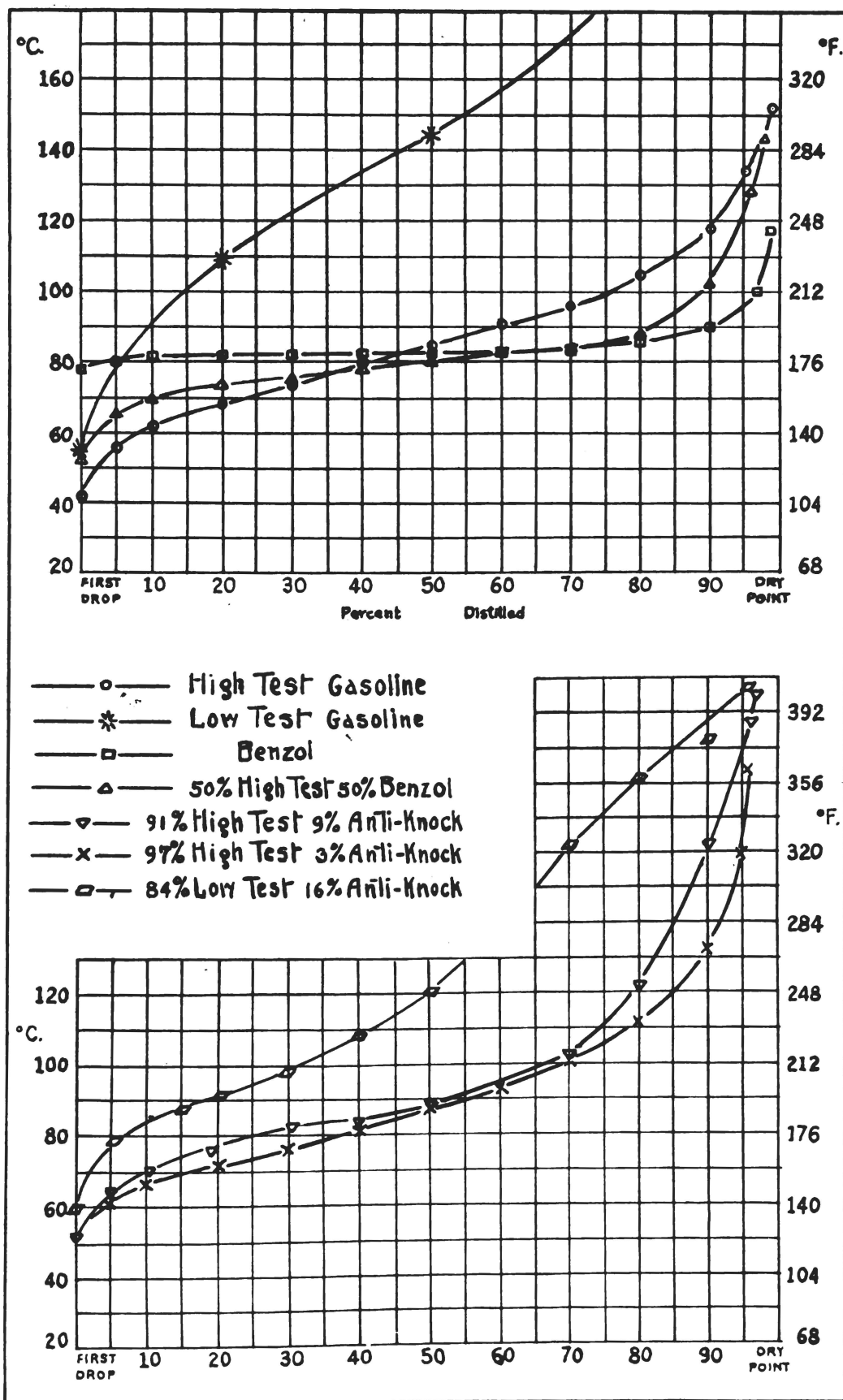


FIG. 8.—Motor fuel distillation.